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Preparation and Characterization of Biodegradable Briquette Prepared from Sugar cane Bagasse and Saw dust

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ABSTRACT: This research work was centered on the study of the combustion characteristics of biodegradable biomass briquettes prepared from sawdust and sugarcane bagasse using sweet potato peel as binder. The two materials were mixed in respective ratio of 30:70, 40:60, 50:50, 60:40 and 70:30. The briquettes were produced using locally available disposed of tins. Combustion characteristics such as proximate analysis, fuel-burning rate and fuel ignition time of the produced briquettes were determined. Results show that briquette with sample composition of 60:40 has better calorific value of 24117.81kJ/kg and sample with ratio 50:50 has lowest calorific value of 21273.63kJ/kg. The average mean of the parameters tested were 18.00±1.954%, 14.2±1.483%, 27.5±0.791%, 40.30±4.366%, 82.00±1.574%, 5487.63±251.951 kcal/g, 119.6±12.992sec and 0.5072±0.0632g/min for Moisture content, Ash content, Volatile Matter, Fixed carbon content, Total solids, Calorific value, and Ignition time and burning rate.

KEYWORDS: Biomass, Biodegradable, Bagasse , Sugar cane, Saw dust and Briquette

I. INTRODUCTION

Biomass is the third largest primary energy resource in the world, after coal and oil (Bapat *et al.*, 2014). In all its forms biomass currently provides about 1250 million tons of oil equivalents to primary energy which is about 14% of the world's annual energy consumption (Werther *et al.*, 2000; Hall *et al.*, 2013). The use of biomass feedstock for the substitution of past fuels has an additional importance from climate change consideration since biomass has the potential to be CO_2 neutral research and development efforts towards the conversion of raw biomass feedstock into improved quality fuels (solid, liquid or gas) through biological and thermo-chemical conversion process have been made globally in the last three decades.

Sequel to the increasing adverse environmental impacts related to the use of conventional fossil fuels, there is strong interest worldwide in the development of technologies that exploit renewable energy sources; and also, new measures to limit greenhouse gas emissions are continuously sought. Biomass, a naturally abundant domestic energy source is seen as the most promising energy alternative to mitigate greenhouse gas emissions (Bain, 2004). Waste agricultural biomass is often under- utilized, more also there is rapid increase in volume and types of waste agricultural biomass produced worldwide due to intensive agricultural activities in the wake of population growth and improved living standards. In Nigeria particularly, with a population of over 170 million people, agriculture is the mainstay of the economy contributing more than 40% of the gross domestic product (GDP). In addition, agricultural sector employs more than two-thirds of the total country's work force and provides livelihood for more than 90% of the rural population (IFAD, 2013). The varying categories of these agricultural wastes is becoming a burgeoning problem as rotten waste agricultural biomass emits methane and leachate while open burning by the farmers to clear the lands (a practice very widely practiced in Nigeria) generates CO_2 and other local pollutants. Generally the agricultural wastes in Nigeria could be grouped in to two major classifications; namely the crop residues and the agricultural industrial residues. The major crop residues in Nigeria are the sugarcane trash; straws of millet, corn, wheat, sorghum; maize stalks and cobs; cotton stalks; leaves; roots; barks; branches different types of fibrous materials. The common agricultural industrial residues include timbering residues; oilseeds shells such as groundnut, palm kernel and coconuts; rise husks; cotton wastes; cassava peels; sugarcane bagasse etc.

ISSN: 2350-0328
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Vol. 7, Issue 9 , September 2020

In Nigeria, the huge volume of agricultural waste generated annually, coupled with the decreasing availability of wood fuel has necessitated concerted effort to look for efficient ways of harnessing these waste for energy generation. Direct combustion of raw agricultural waste as fuel feedstock has some obvious disadvantages including difficulty in controlling the burning rate of the biomass, difficulty in mechanized feeding supply, low heat density, difficulty in stock handling and transportation as well as large storage requirements. Most of these problems are associated with the low bulk density of the agricultural waste. One approach to checkmate these setbacks and efficiently utilize agricultural wastes as fuel is by their densification to produce charcoal briquettes.

II. MATERIALS AND METHODS

A. Methodology

A.1 Biomass Feedstock Preparation

Saw dust and sugar bagasse which are traditionally considered as waste were collected from wood workshop around Yan Katako in Katsina Metropolis and around central market premises where sugarcane is sold. They were sorted and dried to reduce the moisture content of the feedstock to ensure effective carbonization. The dried samples were shredded to small sizes to provide more surface area for the carbonization.

A.2 Carbonization

The Saw dust and sugarcane bagasse biomass were carbonized using the conventional drum method (Emerhi, 2011). The carbonizer is a simple cylindrical design fabricated to provide a means of creating low oxygen environment; it was fabricated using a drum of about 90 cm in height and 60 cm diameter with an opening at the top for loading the saw dust and sugarcane bagasse feed stocks. A suitable metal plate was constructed and was used as cover for the top opening of the drum during firing.

The samples were fed to a reactor at a manageable batch of 5kg each. A fire port was provided at the bottom of the drum and was light through the wicks. At the start of the carbonization process the lid was left open for approximately 10 minutes for the volatile gases to escape. The lid was then closed thereafter; properly sealed to prevent air from entering. The biomass material was left to carbonize for 45 - 60 minutes. The fully carbonized material was collected for further processing.

A.3 Crushing and Sieving

The carbonized biomass materials were grinded to fine particles and sieved using a 200 micron sieve. The sieved pulverised charcoals were measured and divided into four (4) portions of 1kg each

A.4 Materials preparation

The materials used in this study are sawdust and sugarcane bagasse. The samples were dried for 7 days for constant mass. The sugarcane bagasse was grinded with a grinder. The materials were then sieved through the screens of 0.7 mm (for sawdust) and between 1.5 and 2.41 mm (for sugarcane bagasse). Sweet potato peels were used as a binding agent.

A.5 Production of briquette samples

The briquettes were produced using cylindrical mould made from tins. Briquettes of varied biomass proportions were produced by blending the materials; sawdust and sugarcane bagasse in various proportions of 30:70, 40:60, 50:50, 60:40, and 70:30 respectively. For each proportion of briquette, three pieces were produced and 13.8% (18 g) Sodium silicate (Na_2SiO_3) combined with potato peels were used as binder.

A.6 Characterization of the sample prepared

A.6.1 Moisture content

The presence of moisture in a fuel usually has the resultant effect of high ignition time, low calorific value and it also makes the fuel to evolve excessive smoke. The mass of the samples was taken immediately after compression and noted and the mass taken after 5 days of drying in still air at room temperature when a constant mass was attained. The moisture content was determined using

$\% \, Moistureloss = (mb - ma/)$ X100%

Where mb is the mass of fuel immediately after compression and ma is the mass of fuel after drying in still air.

A.6.2 Percentage ash content

The ash content of the solid fuel is the amount of non-aqueous residue that remains after a fuel sample has been burned completely. The Percentage ash content was determined by heating 2 g of the briquette samples in a furnace at a temperature of 550°C for two hours (2 hrs) when it was found to be completely converted to ash (ASTM, 2004; Psomopoulos, 2014). The mass of the fuel was noted before burning in a furnace, and the weight of the ash was measured with a digital weighing scale after cooling in a natural convection air. The percentage ash content was determined (Psomopoulos, 2014).

ISSN: 2350-0328
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Vol. 7, Issue 9 , September 2020

$Percentage ash content = A-C/ B-C \times 100$

Where A is the mass of the crucible with the ash, B is the mass of the crucible with the briquette, and C is the mass of the crucible.

A.6.3 Volatile matter

The volatile matter of the produced briquette was determined in line (ASTMD, 2004). The residual dry sample from moisture content determination was heated at 300°C in a furnace for 30 minutes to drive off the volatiles. The volatile matter was obtained using according to Onuegbu *et al.,* (2010).

$Volatile matter$ (%) = $E-F/ E \times 100$

Where E is the mass of the briquette before heating and F is the mass of the briquette after heating.

A.6.4 Fixed carbon content

Fixed carbon represents the amount of burnt carbon in a material by drawing air through hot bed of a fuel. The fixed carbon content of the samples was obtained using Equation as used by Onuegbu *et al*., (2010).

FC (%) = 100− (MC (%) +VM (%)+AC (%))

A.6.5 Calorific value

The calorific value is also known as heating value or energy value of a briquette is the amount of heat liberated per unit mass of the briquette. Calorific values were calculated using the fixed carbon content and volatile matter of the briquettes according to the method and Equation presented in Adetogun *et al.,* (2013).

$HV = 2.326(147.6FC + 144\,VM)/kg$

Where HV is the calorific value, FC is the percentage of fixed carbon content, and VM is the percentage of volatile matter.

A.6.6 Fuel burning rate

Briquette burning rate was determined using the method used by Onuegbu *et al.,* (2010). Briquettes of known mass were ignited over the flame from a Bunsen burner. Throughout the combustion process, a stopwatch was used to take the time, until the briquettes were completely burnt. The fuel-burning rate was then computed using Equation below as used by Kuti and Adegoke, (2008):

$Br = WT/ TT$

Where Br is the fuel-burning rate, WT is the weight of fuel burnt, and TT is the time taken.

A.6.7 Ignition time

Ignition time is the total time measured in seconds, that it will take a briquette to start burning when in contact with flame. It was carried out on each briquette sample to determine the required time for each sample to ignite as specified by Davies *et al.,* (2013). The test was carried out at room temperature, each sample was ignited using flame from a Bunsen burner, and stopwatch used to record the time. The time was measured from immediately the briquette come in contact with the flame, until a uniform flame was establish on the briquettes. The time required for the flame to ignite the briquette was recorded as the ignition time.

A.6.8 Total solids

Total solid was obtained by deducting the amount of moisture content. This can be calculated using the equation below:
Total solids (%) = 100- (% moisture content)

III. RESULTS AND DISCUSSION

A. Results

The results from the analyses are presented in tabular form below.

Table 1: Result of the moisture content

Sample ratio Sw Sb	Mass of fuel before drying (g)	Mass of fuel after drying (g)	Moisture content (%)
30 : 70	80	65	18.75
40 : 60	80	66.12	17.35
50 : 50	80	63.33	20.84
60 : 40	80	67.54	15.58
70 : 30	80	66.03	17.46

Key: Sw stands for saw dust and **Sb** for sugarcane bagasse

ISSN: 2350-0328
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Vol. 7, Issue 9 , September 2020

Table 2: Results of the Ash content analysis

Sample ratio Sw Sb	Mass of fuel (g)	Mass of Ash (g)	Ash content (%)
30 : 70	2	0.25	12.50
40 : 60	2	0.29	14.50
50 : 50	2	0.33	16.50
60 : 40	2	0.27	13.50
+ `	2	0.28	14.00

Key: Sw stands for saw dust and **Sb** for sugarcane bagasse

Table 3: Results of the Volatile organic matter

Sample ratio Sw Sb	Mass before heating (g)	Mass after heating (g)	Volatile organic matter (%)
30 : 70	2	1.46	27
40 : 60	2	1.47	26.50
50 : 50	2	1.43	28.50
60 : 40	2	1.45	27.50
70 : 30	2	1.44	28.00

Key: Sw stands for saw dust and **Sb** for sugarcane bagasse

Table 4: Results of the fixed carbon content

Sample ratio Sw Sb	Volatile organic matter (%)	Ash content (%	Moisture content (%)	Fixed carbon content (%)
30 : 70	27	12.50	18.75	41.75
40 : 60	26.50	14.50	17.35	41.65
50 : 50	28.50	16.50	20.84	34.16
60 : 40	27.50	13.50	15.58	43.42
70 : 30	28.00	14.00	17.46	40.54

Key: Sw stands for saw dust and **Sb** for sugarcane bagasse

Table 5: Result of the total solids analysis

Sample Ratio Sw Sb	Moisture content (%)	Total Solids (%)
30 : 70	18.75	81.25
40 : 60	17.35	82.65
50 : 50	20.84	79.16
60 : 40	15.58	84.42
70 : 30	17.46	82.54

Key: Sw stands for saw dust and **Sb** for sugarcane bagasse

Table 6: Results of the calorific value

Sample ratio Sw Sb	Volatile matter (%)	Fixed carbon (%)	Calorific value (kJ/kg)	Calorific value (kcal/kg
30 : 70	27	41.75	23377.00	5565.95
40 : 60	26.50	41.65	23175.19	5517.90
50 : 50	28.50	34.16	21273.63	5065.15
60 : 40	27.50	43.42	24117.81	5742.34
70 : 30	28.00	40.54	23296.53	5546.79

Key: Sw stands for saw dust and **Sb** for sugarcane bagasse

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 7, Issue 9 , September 2020

Table 7: Results of the Ignition and burning rate analysis

Sample ratio Sw Sb	Ignition time (s)	Fuel burning rate (g/mn)
30:70	129	0.4651
40:60	127	0.4724
50:50	97	0.6185
60:40	121	0.4959
70:30	124	0.4839

Key: Sw stands for saw dust and **Sb** for sugarcane bagasse

Table.8: Statistical representation of the results

Parameter	Unit	Average mean	Standard deviation
Moisture content	%	18.0	±1.954
Ash content	%	14.2	±1.483
Volatile Matter	%	27.4	±0.791
Fixed carbon content	%	40.30	±4.366
Total solids	%	82.0	±1.574
Calorific value	kcal/g	5487.63	±251.951
Ignition time	S	119.6	±12.992
Burning rate	g/min	0.5072	±0.0632

Key: Sw stands for saw dust and **Sb** for sugarcane bagasse

B. Discussion

B.1 Moisture content

Table 3.1 shows the result of the moisture content of different percentage combination by weight of sawdust and sugarcane bagasse used in this study. From table 3.7, it has been found that the average moisture content of the prepared briquette was found to be 18%. According to Ajobo, (2014) the ideal operating ranges of moisture content should be between 10.15% for making briquette, also Thailand Industrial Standards Institute (TISI) mandates that the moisture content of solid fuel briquettes not exceed 8% by weight (Emerhi, 2011). It can be observed from Table 3.1 that the fuel with proportion 60:40 has the minimum moisture of 15.58%, which is within the value recommended (Ajobo, 2014). Other fuels proportions have moisture content above this value, especially in 50:50 where it is observed to be highest. This can be said to be as a result of the hygroscopic nature of both sawdust and sugarcane bagasse and the method used in processing the raw material (sun drying) may likely to be responsible. According to Psomopoulos, (2014) moisture content for solid fuel depends on the target market as the moisture content that a solid fuel produced for industrial purpose is expected to be lower than that of a solid fuel produced for commercial purposes and also, moisture content of commercial briquette depends on country policy on the refuse developed fuel as Finland, Italy and United Kingdom requires that the moisture content by percentage weight (% wt.) of solid fuel should be maximum of 35%, 25% and 28% respectively (Psomopoulos, 2014). If these standards are adopted, then the moisture content obtained in this study is generally acceptable by the standard.

B.2 Ash content

Ash, which is the inorganic matter left out after complete combustion of biomass was found to be between the ranges 11.18% and 16.25% as it can be seen in Table 3.2. This is the percentage of impurity that wills not combust during and after combustion of the fuel. The average mean value of moisture the ash content was found to be 14.2%. Biomass of higher ash content tends to consume more fuel than the biomass of lower ash content (Hassan *et al.*, 2013). According to Jekayinfa *et al.*, (2005) percentage ash content is one of the factors that affect specific fuel consumption of the fuel negatively, the percentage ash content as reported by Kishor and Singh, (2015) for coal was 18.23%, while the present study recorded ash content that is generally below this value. Jekayinfa *et al.*, (2005) reported the ash content values for some agricultural wastes as follows; Palm oil effluent 10.97%, Corn cob 4.85%, Yam peels 4.56%, Mango peels 4.33% and Orange peels 2.66%. Prasityousit and Muenjina, (2013) were able to record values between 9.84% and 14.39% of ash content for some municipal waste, while Psomopoulos, (2014) recorded 22.5% ash content for rubber and Kers et al., (2010) recorded 36% ash content for briquettes made from fibre material and refuse-derived fuel (RDF). The present study ash content values, which are generally below 16.4% with the exception of ratio 50:50, were within the range of these values for obtained ash contents. The low ash contents indicate that the fuel briquettes are generally suitable for thermal utilization.

B.3 Volatile matter

The result of volatile matter obtained for this study is shown in table 3.7 above, the average mean value of volatile matter of the briquette sample prepared was found to be 27.5±0.791%. The volatile matter was observed to be maximum in the fuel ratio 50:50 and lowest in the fuel ratio 40:60.

B.4 Fixed Carbon content

The fixed carbon content obtained is tabulated in Table 3.4. The fixed carbon content for this work is observed to be highest in the fuel with ratio 60:40 having 43.42%, and lowest in the fuel with ratio 50:50 having 34.16%, this result is influenced by the percentage moisture content, ash content and volatile matter present in these fuel briquettes as the fixed carbon contents is dependent on these factors. So far, the average fixed carbon content as presented in table 3.7 above was found to be 40.30%.

B.5 Calorific value

The average result for calorific values obtained in this work is 23048.03kJ/kg (5487.63kcal/kg) as shown in Table 3.7. The calorific values in this study are lower compared to that obtained by (11nfor briquettes made from Afzelia Africana bonded with starch; this may likely due to the fact that carbonized his materials (Emerhi, 2011). The calorific value obtained in this study compared favourably with those recorded for coconut husk (Jekayinfa *et al.*, 2005) and that of maize cob with a calorific value of between 20930 kJ/kg and 24970 kJ/kg obtained (Adetogun *et al.*, 2013).
In this study, the average heating value obtained is higher than the calorific value of bagasse at 20567 kJ/kg, wood charcoal at 8270kJ/kg and saw dust 19534kJ/kg recorded for briquettes from a mixture of palm kernel cake (PKC) with sawdust and 18936 kJ/kg recorded for sawdust with some hardwood species (Hroncová *et al.*, 2014). This is higher than the recommended standard value of 17500 kJ/kg for a material to be regarded as having adequate calorific value Austria Standard (ONORM M7135), Sweden Standard (SS 187120) and Germany Standard (GS/DIN51731). This implies that the calorific values obtained are reasonable for thermal utilization

B.6 Total Solids

The total solids are expressed in percentage. It is the total dry biomass after the removal of moisture content. All the ratios were found to have contained a considerable amount of solids which in turns indicated the potency as well as suitability of the samples under study to be used in the preparation of briquettes. The total average total solid was found to be 83±1.574%. The composition 60:40 was found to have the highest amount of solids with combinations 50:50 having the least amount.

B.7 Fuel burning rate

The burning rate values of the energy sources ranged between 0.4651 (g/min) and 0.6185 (g/min) as presented in Table 3.7. The rate is observed to be lowest in the fuel ratio 30:70. The average burning rate was found to be 0.0632(g/min). This observation could be adduced to porosity (even though its porosity is less than that of 20:50:30 and 20:60:20) exhibited between inter and intra-particles which enable easy infiltration of oxygen and outflow of combustion briquettes. It is also believed that briquettes with higher density will have longer burning time (10). It is observed that the burning rate is highest in the fuel ratio 50:50 where all the ratios are equally pronounced.
Prasityousit and Muenjina (2013) used rejected material of municipal waste composting for solid fuel production and they obtained a burning time that ranges between 188 min and 211 min, Alakangas (2009) also obtain a burning rate between 1.63 (g/min) and 2.25 (g/min) for briquettes made from water hyacinth and phytoplankton scum as binder, Kishor and Singh (2015) obtained the burning rate values of 1.5 (g/min) to 3.5 (g/min) for coal briquettes made from spear grass (ImperataCylindrica) and Markson*et al.,* (2013) obtained values between 0.97 (g/min) and 2.05 (g/min) as burning rate for briquettes made from water hyacinth. A low burning rate like that obtained in this work is of great advantage compared to the past work because the briquettes do not burn-out rapidly, as a result, it continues to generate useful energy for a longer period of time.

ISSN: 2350-0328
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Vol. 7, Issue 9 , September 2020

B.8 Ignition time

The ignition time of the studied fuels varied between 97 seconds for the fuel ratio 50:50 and 129 seconds for fuel ratio 30:70 as can be observed in Table 7. According to Davies *et al.*, (2013) briquettes for domestic use must be easily ignitable, with low porosity index, low volatile content and low ash content. The values of ignition time 119.6±12.992 obtained in this work falls between the ranges of ignition time of 84.33±0.28 and 138.29±0.19 seconds reported by Davies *et al.,* (2013) the values of between 33 seconds to 186 seconds obtained by Kishor and Singh (2015) and that of Hassan *et al.,* (2013), which is between 65 and 273 seconds. The results of this work can be said to be reasonable and acceptable

IV. CONCLUSION

The carbonization of waste sugarcane bagasse and saw dust agricultural biomass was conducted using locally fabricated metal kiln. Four briquettes grades were produced, the physical and combustive properties of the briquette grades were determined. It was concluded that the conversion of waste sugarcane bagasse and saw dust biomass resources into briquette charcoal is an effective means of managing this solid wastes. Furthermore, due to the abundance of waste agricultural biomass resources and as well naturally occurring binder materials which can be sourced locally, carbonized briquetting has the potential to provide employment to the teaming restive youth in northern Nigeria

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Vol. 7, Issue 9 , September 2020

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